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Adaptation of Recently Released Andean Common Bean (*Phaseolus vulgaris* L.) Varieties for Potential Areas in Wolaita Zone, South Ethiopia Region

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Abstract

An experiment was conducted during the growing seasons of 2022 to 2023 at Areka and Kokate stations to evaluate and select high-yielding Andean common bean varieties, focusing on seed yield and associated traits. Seven common bean varieties, along with a local check, were subjected to evaluation using a randomized complete block design with four replications. The analysis of variance revealed a significant difference (P < 0.01) in seed yield, pod per plant, seed per pod, plant height, days to 50% flowering, and days to 90% flowering between varieties, locations, and their interactions. The overall average for these traits was 1636.79 kg/ha, 21.05, 5.3, 47.09 cm, 41.12, and 82.77, respectively. Additionally, these traits showed significance (P < 0.05) at both Areka and Kokate stations over two years. Tatu and Ibaddo appeared as the top-performing genotypes, yielding 1838 kg/ha and 1959 kg/ha, respectively. On the other hand, Tafach (1449 kg/ha), DRK (1369 kg/ha), and Ado (1318 kg/ha) exhibited relatively lower yields. Pearson correlation analysis indicated a positive correlation of seed yield with pod per plant (P < 0.2817, 0.001), seed per pod (P < 0.1130, 0.2041), plant height (P < 0.1207, 0.1746), stand count at harvest (P < 0.518, 0.001), while negative correlations were observed with days to 50% flowering (P < –0.111, 0.211) and days to 90% maturity (P < –0.0577, 0.518). Therefore, based on their top yields, varieties Tatu (1838 kg/ha) and Ibaddo (1959 kg/ha) are recommended for growing in the tested areas and regions with similar agro ecological zones.

Keywords: Common bean, evaluation, selection, traits, yield

INTRODUCTION

The haricot bean, also known as the common bean (*Phaseolus vulgaris* L.), belongs to the legume family Leguminosae [1]. Its annual production is about 8.5 million metric tons in the world, of which three-fourths are produced by low-income tropical countries. The production share for Latin America and Sub-Sahara Africa were 46.7% and 24.1% respectively [2]. From the average world common bean production, 77.3% and 22.7% were covered by developing and developed countries respectively [1]. The crop is considered the main source of protein for the poor in Eastern and Southern Africa [2].

Its production is primarily concentrated in the Sub-Saharan region in Africa (Western, Southern, and Eastern Africa), it is also cultivated in densely populated areas of the Eastern and Southern parts of the continent to meet local consumption needs, support soil fertility, and enhance farming system diversity [3]. Common bean is an herbaceous annual plant that was independently cultivated and domesticated in ancient Mesoamerica and the Andes [4]. This legume crop holds immense significance as it serves various purposes, including

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being a crucial source of home consumption, a key input for the food industry, a contributor to soil fertility maintenance, a server of earning foreign exchange income, and a stabilizer of farming systems [5].

In Ethiopia, haricot bean cultivation is prominent in lowland regions with hot and humid climates, although Andean gene pools can be successfully grown in elevations ranging from 1500 to 2200 meters above sea level [6]. In the 2021/22 cropping main season, Ethiopia allocated a total area of 339,350.34 hectares for common bean production, yielding an impressive 584,157.96 tons [7]. Consequently, the common bean stands out as Ethiopia's most crucial pulse crop, both in terms of expansive cultivation areas and substantial contributions to overall production and soil fertility maintenance.

In Ethiopia, the common bean found its way into various culinary delights, featuring prominently in diverse food preparations. Whether served as "nifro" (a boiled blend of maize and beans), "Bilando" (a boiled bean mixture with "Kocho"), or as an integral ingredient in "wot" (a local stew), common beans have become staples in traditional dishes. While these culinary traditions were initially prevalent in certain Southern regions of Ethiopia, they have now permeated the entire country, becoming well known in towns nationwide [8].

Despite the common bean's pivotal role in ensuring food security, providing essential nutrients, maintaining soil fertility, and contributing to foreign currency earnings, there is a notable gap among farmers to use recently released improved varieties [5]. Instead, outdated varieties continue to dominate the region's production area. Consequently, this trial has been done to identify, from the Andean gene pool, varieties that exhibit wider adaptability and superior yields, using yield and associated traits as the primary selection criteria.

MATERIALS AND METHODS

Description of the Study Area

The Kokate and Areka stations are situated in the Wolaita zone, serving as the political and administrative center of the South Ethiopia region. The experiment extended the production seasons of 2022 to 2023 and was conducted in these specific locations. The description of the study locations is shown in Table 1.

Table 1. Description of the study locations during the 2022 to 2023 cropping seasons

Study Sites	**Altitude (Masl)**	**Annual Rain Fall (mm)**	**Soil Type**	**Temperature (°C)**		**Global Positioning**	
				Max	*Mini*	*Latitude (N)*	*Longitude (E)*
Kokate station	2156	1655	Nitisols	24.2	13.6	6°85'28"	37°76'10"
Areka station	1780	1438	Alisols	26.2	14.2	7°06'97"	37°69'72"

Note: masl = meter above sea level.

TREATMENTS, EXPERIMENTAL DESIGN AND PROCEDURES

Before starting the experiment, careful selection and preparation of land was conducted at the Kokate and Areka stations. Subsequently, seven common bean varieties and a local check were arranged in a Randomized Complete Block Design with four replications at both Areka and Kokate stations in the South Ethiopia region. The treatments employed for the experiment are outlined in Table 2. The spacing between rows and plants was set at 0.4 m and 0.1 m, respectively. Each plot consisted of six rows (2.4 m) with a length of 4 m, and the net harvested row was four (1.6 m). The spacing between plots and replications was 0.4 m and 1 m, respectively. Inorganic fertilizer NPS (19N, $38P_2O_5$, and 7S) and seeds were sown at rates of 121 kg/ha and 100 kg/ha, respectively. Cultural practices, such as weeding, fertilization, and earth-up were carried out by established practices to encourage root growth and nutrient absorption.

Table 2. Descriptions of the common bean varieties tested at two stations during 2022–2023 in Wolaita zone, South Ethiopia region

S.N.	Variety Name	Maintainer	Year of Release	Seed Color/Size
1.	Remeda/AFR-702-1	HARC	2014	Large red
2.	Fetenech/DAB 277	HARC	2017	Large Red mottled
3.	Ibaddo/AFR- 277	ARARC	2003	Large speckled
4.	Acos-red / DRK	MARC	2007	Large dark red
5.	Local check	Farmers	Locally dominant	Large Red
6.	Tafach /SAB 632	MARC	2015	Large red speckled
7.	Ado (SAB 736)	MARC	2015	Large white
8.	Tatu (ETAW-01-L-7-6K)	HARC	2014	Large black speckled

Note: ARARC = Areka Agricultural Research Center, HARC = Hawassa ARC, MARC = Melkassa ARC. Source: Adopted from Crop variety register. Issue no. 24. Addis Ababa, Ethiopia.

DATA COLLECTION

To evaluate the varieties, data on seed yield and associated traits were collected. Crop phenology data, comprising days to 50% emergence, days to 50% flowering, and days to 90% maturity, were recorded on a plot basis [9]. Additionally, yield-contributing parameters, including pods per plant, seeds per pod, and plant height (cm), were obtained from five randomly selected plants within the middle four rows. Data on 100-seed weight (g) and seed yield (kg/ha) were gathered from the harvest of the four rows. Notably, diseases like angular leaf spot, common bacterial blight, aschochyta blight, and anthracnose, prevalent in both experimental locations, but were not considered in this paper.

DATA ANALYSIS

The seed yield and associated traits were subjected to analysis of variance using the General Linear Model (GLM) of SAS (Statistical Analysis Software) Version 9.2 [10] for individual locations and combined analysis. Before combining the data for ANOVA, Bartlett's test was employed to assess the homogeneity of error variance for each trait and separate location over two successive years [11]. Mean separation was conducted at a 5% probability level using LSD (Least Significant Difference). Additionally, correlations among yield and associated traits were analyzed [12].

The RCBD Model used for the experiment:

$$Y_{ij} = \text{Mean} + \text{Block}_i + \text{Trt}_j + \text{Error}_{ij},$$

where treatments were j^{th} variety fixed effects, and block and error are random effects [12].

RESULTS

Table 3 presents the mean square values for yield and associated traits of eight Andean common bean genotypes evaluated at Areka station over two consecutive years. The significant differences for mean squares of the traits are shown in Table 3.

Besides, the analysis of variance (ANOVA) for seed yield and associated traits of eight Andean common bean genotypes conducted at Kokate station is presented in Table 4.

Moreover, the combined analysis of variance, i.e., treatments, locations and their interaction are shown in Table 5.

The combined means of seed yield and associated traits for eight Andean common bean genotypes tested at Kokate and Areka stations are presented in Table 6. These mean values differences showed performance differences among the tested varieties.

The mean seed yield of eight common bean genotypes' mean performance in separate years and locations is shown in Table 7. This table indicates the mean seed yield value of each variety in the respective locations for the tested years.

Table 3. Mean square of yield and yield-associated traits of Eight Andean common bean genotypes tested at Areka station during the 2022 to 2023 cropping seasons.

SV	2022						2023					
	Mean Square						*Mean Square*					
	YLD	*DTF*	*DTM*	*PH*	*PDPPT*	*SDPPD*	*YLD*	*DTF*	*DTM*	*PH*	*PDPPT*	*SDPPD*
Rep	5252233	0.54	0.33	218	5.87	3.75	24725	0.2	0.33	204.	9.03	0.03
Trt	698170*	40.55*	260.85*	1470*	218.55*	3.37*	305528*	8.41*	260.8*	183.7*	50.35*	0.53*
Error	204222	0.68	0.33	110	1.73	3.77	56902	0.4	0.33	142	12.3	0.48
Mean	1202	40.4	81.25	44	25.06	4.0	1902	41	82.3	49.2	27.6	5.53
CV	37.0	2.04	1.13	4.05	5.25	12.6	12.54	1.5	0.7	24.2	12.7	12.57
Sdv	319.6	0.63	0.69	7.4	1.35	1.37	168.7	0.4	0.4	5.90	2.48	0.49

Note: YLD = yield in kg/ha, DTF = days to 50% flowering, DTM = days to 90% maturity, PH = plant height (cm), PDPPT = pod per plant, SDPPD = seed per pod, Sdv = standard deviation.

Table 4. Mean square of yield and yield associated traits of Eight Andean common bean genotypes tested at Kokate station during 2022 to 2023 cropping seasons.

SV	2022						2023					
	Mean Square						*Mean Square*					
	YLD	*DTF*	*DTM*	*PH*	*PDPPT*	*SDPPD*	*YLD*	*DTF*	*DTM*	*PH*	*PDPPT*	*SDPPD*
Rep	1849718	0.54	0.34	4.8	5.78	1.58	3731	0.54	0.35	4.86	2.1	0.87
Trt	774819*	40.5*	261.2*	15.3*	219*	1.92*	95495*	40.5*	259.2*	15*	20.8*	1.13*
Error	196064	0.68	0.34	4.00	1.75	0.63	5024	0.68	0.35	4.0	8.6	0.26
Mean	1595	40.5	81.4	49.5	24.9	6.37	1648.	39.4	82.25	49	11.9	4.56
CV	27.76	2.05	0.75	4.05	5.3	12.5	4.30	2.10	1.75	4.1	24.6	11.0
Stdv	313.5	0.58	0.40	1.4	1.94	0.56	50.12	0.58	0.40	1.4	2.08	0.35

Note: YLD = yield in kg/ha, DTF = days to 50% flowering, DTM = days to 90% maturity, PH = plant height (cm), PDPPT = pod per plant, SDPPD = seed per pod, SV = source of variation, Stdv = standard deviation.

Table 5. Combined ANOVA of yield and related traits of Eight Common bean genotypes tested at Areka and locate stations of south Ethiopia during the 2022 to 2023 cropping seasons.

SV	DF	Mean Square Value					
		YLD	***DTF***	***DTM***	***PH***	***PDPPT***	***SDPPT***
loc	1	29040.5*	175.78*	520.03*	24.5*	820.125*	3.45*
rep(loc)	6	1644204.9	0.77	0.35	30.65	31.56	1.46
Yr(loc)	2	2026623	77.032	213.03	330.25	1887.59	31.16
Trt	7	836374.46*	37.067*	930.08*	562.76*	205.12*	1.76*
Error	104	235916.2	0.682	23.064	121.02	28.72	1.38
loc*Trt	7	170056.36 *	52.25*	168.23*	522.072*	17.86*	1.49*
Yr*Trt(loc)	14	433790.75	-	-	-	-	-
CV (%)		29.67	2.00	5.8	23.36	25.46	22.17
Mean		1636.79	41.12	82.77	47.094	21.05	5.31
LSD		341	0.5788	3.36	7.72	3.76	0.83

Note: YLD = yield in kg/ha, DTF = days to 50% flowering, DTM = days to 90% maturity, PH = plant height (cm), PDPPT = pod per plant, SDPPD = seed per pod, SV = source of variation, LSD = Least Significant Difference.

The correlation analysis of seed yield and associated traits for eight common bean genotypes is presented in Table 8. In addition to the mean seed yield performance of the varieties tested over the years and locations; the significant, positive, and negative contributions of each trait with each other were analyzed to identify the future focus traits for common bean varieties improvement in the tested areas and similar agro-ecological zones.

Table 6. Mean values of yield and related traits of Eight Andean common bean genotypes tested at Areka and Kokate stations of South Ethiopia during 2022 to 2023 cropping seasons

Variety	Mean Values					
	YLD	***DTF***	***DTM***	***PH***	***PDPPT***	***SDPPD***
Local check	1747abc	43.69a	90.75a	46.8bc	18.13c	5.125ab
Remeda	1643bcd	41.44b	79.25d	54ab	25.86a	5.25ab
DRK	1418.3cd	39.86c	83.63c	42.87c	17.125c	4.94b
Tatu	1888.3ab	41.36c	89.37ab	43.86c	20.06c	5.25ab
Fetenech/ DAB 277	1523.1cd	38.88f	69.18f	43.13c	20.56bc	4.94b
Ibaddo/AFR 722	2008.6a	40.75d	75.13e	44.3c	24.25ab	5.75ab
Tafach/SAB 632	1498.8cd	42.56b	87.94ab	43.18c	17.25c	5.82a
Ado/SAB 736	1367.3d	40.32de	86.88bc	58.56a	25.12a	5.375ab
CV	29.67	2.00	5.8	23.36	25.4	
Mean	1636.79	41.12	82.77	47.09	21.05	

Note: YLD = yield in kg/ha, DTF = days to 50% flowering, DTM = days to 90% maturity, PH = plant height (cm), PDPPT = pod per plant, SDPPD = seed per pod, SV = source of variation, CV = coefficient of variation.

Table 7. The mean seed yield (kg/ha) of eight common bean genotypes tested at Areka and Kokate stations of South Ethiopia during the 2022 to 2023 cropping seasons.

Varieties Local Check	2022		2023		Mean Yield	Rank
	Areka	***Kokate***	***Areka***	***Kokate***		
	1595	1609	1842	1540	1747.0	3
Remeda	1170	1888	1800	1515	1643.0	4
DRK	799	1253	1538	1884	1418.0	7
Tatu	1549	1924	2274	1606	1888.3	2
Fetenech/DAB 277	667	1255	2086	1886	1523.0	5
AFR 722 /Ibaddo	1641	2359	2184	1650	2008.6	1
SAB-632 /Tafach	895	1445	1956	1500	1498.8	6
Ado/SAB 736	1098	1028	1537	1607	1367.3	8
CV	14.0	27.76	12.5	14.5		
GM	1201	1595	1901	1648	1636.79	

Note: CV = Coefficient of variation; GM = Grand Mean.

Table 8. Correlation of yield and yield-related traits of eight Andean Common bean genotypes tested at Areka and locate stations of southern Ethiopia during the 2022 to 2023 cropping season.

	DTF	**DTM**	**PDPPT**	**PH**	**SCH**	**SDPPT**
DTF	0.459					
	0.000					
PDPPT	–0.022	–0.0515				
	0.8097	0.5637				
PH	–0.0255	–0.0494	0.3025			
	0.7748	0.5798	0.0005			
SCH	0.3666	0.1938	0.2042	0.1068		
	0.000	0.0284	0.0208	0.2303		
SDPPD	0.0095	0.0179	0.2628	0.1651	0.1258	
	0.915	0.8414	0.0027	0.0626	0.1572	
YLD	–0.1111	–0.0577	0.2817	0.1207	0.5181	0.1130
	0.2118	0.5180	0.0013	0.1746	0.000	0.2041

Note: YLD = yield in kg/ha, DTF = days to 50% flowering, DTM = days to 90% maturity, PH = plant height (cm), PDPPT = pod per plant, SDPPD = seed per pod.

DISCUSSION

Analysis of Variance

The ANOVA revealed a significant difference ($P < 0.01$) for seed yield, days to 50% flowering, days to 90% maturity, plant height (cm), pods per plant, and seeds per pod during the 2022 to 2023 growing seasons (Table 3). The coefficient of variation for qualitative traits, such as days to flowering and days to maturity, was lower compared to quantitative traits, including yield, plant height, pods per plant, and seeds per pod. These differences could be attributed to the fact that a single gene typically controls qualitative traits, whereas multiple genes [13, 14] influence quantitative traits.

Additionally, the standard deviation for most traits, as indicated in Table 3, demonstrated that the values for each parameter fluctuated around the mean rather than being widely dispersed [15]. Numerous researchers have investigated the performance of common bean genotypes across multiple environments, consistently highlighting the importance of seed yield and associated traits [16, 17] aligning with my findings, all these researchers emphasized the significance of the mentioned traits in their respective studies.

According to ANOVA presented in Table 4, there was significant differences ($P < 0.01$) for seed yield (kg/ha), days to 50% flowering, days to 90% maturity, plant height (cm), pod per plant, and seed per pod – all essential parameters for evaluating common bean varieties. Like the observations at the Areka station, the coefficient of variation for quantitative traits was higher than for qualitative characteristics [14]. Numerous studies examining the adaptation of common bean genotypes across various locations have consistently reported significant differences in seed yield and related traits [18–20]. These author’s findings align with the results obtained in this study.

The combined analysis of variance revealed that the interaction between location and treatment was significant ($P < 0.01$) for seed yield (kg/ha), days to 50% flowering, days to 90% maturity, plant height (cm), pod per plant, and seed per pod (Table 5). This suggests variations in genotype performance across locations or the locations discriminated against the varieties or both, during the 2022 to 2023 cropping seasons. This finding agrees with the reports of [21, 22] on the stability and productivity study of common bean-released varieties across various locations in Ethiopia.

The Mean Performance of the Genotypes

Based on the combined means of seed yield and associated traits shown in Table 6, the mean seed yield varied among common bean genotypes, ranging from 1367 kg/ha (SAB 736) to 2008.6 kg/ha (AFR 722). AFR 722/Ibaddo outperformed the recent variety SAB 736 by 19.01%. However, the newly released varieties withstand contemporary weather conditions than the older varieties [23]. The combined mean yield for the tested genotypes over the two cropping seasons was 1636.79 kg/ha, which closely aligns with the national average yield of common beans in Ethiopia (1721.4 kg/ha) reported by ESS (2021/2022). Notably, days to 90% maturity exhibited significant differences across genotypes, with a range of 69.18 days (Fetenech/DAB 277) to 90.75 days (Local check). This suggests that DAB 277 is well suited for short-season “Belg”, ensuring a timely harvest before the onset of long-season rainfall (“Meher”). Pod per plant varied from 17.12 (DRK) to 25.86 (Remeda), while seed per pod ranged from 4.94 (DRK) to 5.82 (SAB 632). This indicates diversity among genotypes, with some exhibiting higher seed per pod and lower pods per plant, and vice versa. It underscores the complexity of seed yield, influenced by various traits and factors beyond just the number of pods per plant and seeds per pod. This finding agrees with the results of various authors who did their experiments on common beans [19–21].

According to the mean seed yield performance of common bean varieties shown in Table 8, AFR 722 (2008.6 kg/ha) common bean genotype was ranked first followed by Tatu (1888.3 kg/ha). Relatively, the less-yielding genotypes were Ado/SAB 736 (1367.3 kg/ha), DRK (1418.0 kg/ha), and SAB-632 /Tafach (1449 kg/ha) which were ranked 8^{th}, 7^{th} and 6^{th}, respectively, in which yield was below the national average (1727 kg/ha) of 2022 cropping year [7].

Correlation of Characters

The correlation analysis of seed yield and associated traits for eight common bean genotypes is presented in Table 8. Seed yield exhibited positive correlations with pod per plant ($r = 0.2817$, $p = 0.0013$), plant height ($r = 0.1207$, $p = 0.1746$), stand count at harvest ($r = 0.518$, $p = 0.000$), and seed per pod ($r = 0.113$, $p = 0.204$). Conversely, it showed negative correlations with days to flowering ($r = –0.111$, $p = 0.211$) and days to maturity ($r = –0.0577$, $p = 0.518$). Seed per pod demonstrated positive but non-significant correlations with days to 50% flowering, days to 90% maturity, stand count at harvest, and plant height. At the same time, it exhibited a significant positive correlation with pod per plant. Plant height was significantly correlated ($r = 0.3025$, $p = 0.0005$) with pod per plant but shown negative correlations with days to 50% flowering and days to 90% maturity. Various authors have noted correlations between yield and related traits. For example, studies on common beans [16, 20, 24] have highlighted such associations.

CONCLUSIONS

Common bean is produced to improve soil fertility, for home consumption, to earn export income, and to enhance farming system diversity in Ethiopia. Among eight Andean gene pool common bean genotypes tested at Areka and Kokate districts of the South Ethiopia region from 2022 to 2023 cropping seasons, Tatu (ETAW-01-L-7-6K) and Ibaddo (AFR 722**)** out-yielded other varieties with an average yield of 1838 kg/ha and 1959 kg/ha respectively. Besides, the Pearson correlation indicated positive and significant seed yield with seed per pod, pod per plant, plant height, and stand count at harvest whereas there was a negative correlation with 50% flowering and 90% maturity. Hence, among the tested varieties, Ibaddo and Tatu were recommended for large-scale production in the tested districts and areas with similar agro-ecological zones as the first and second options, respectively.

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